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SoLoArc: A free-field, multisensory localization tool for scientific inquiry in undergraduate education

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Introduction

Sound localization has been studied empirically for almost a century. In humans, sound localization is used to pinpoint, identify and respond to sounds in the surrounding environment. Both azimuth (horizontal plane) and elevation (vertical plane) have been studied extensively with free field devices (Tarby, Zatorre & Voss, 2013) and with headphones (McPherson & Sabin, 2013).

We have developed a free-field audiovisual stimulus presentation device to engage undergraduate students in developing design, engineering and research skills while also exploring concepts in sensory neuroscience. Beginning as student-driven independent research project in a Cellular & Molecular Neuroscience course, the SoLoArc (SOund LOcalization Arc) is the result of a collaborative effort between undergraduate students, faculty, and staff. The device will be used as an instructional aide in undergraduate Psychology and Neuroscience courses, and for student and faculty research. This project is the culmination of a successful and intensive independent research course (a two-semester design and build) coupled with the passion of a group of undergraduate students.

Our approach put the creation of a large apparatus in the hands of the students, who were closely supervised and mentored by faculty and staff. The process provided experience in experimental apparatus design, engineering, and fabrication. While such a pedagogical approach is often overlooked in the undergraduate curriculum, it can be an important part of teaching the scientific process.

Methods

The methods of this project can be broken down into two distinct phases. The experience of designing and building the apparatus represents one valuable teaching tool. The other is the knowledge to be gained by utilizing this piece of equipment in the classroom and through research.

Design and Construction of the SoLoArc:

- Students designed the overall structure and electronics of the SoLoArc in close collaboration with a Physics technician and shop manager
  - This involved both a theoretically grounded design and engineering phase, and a procurement phase
  - Funding provided by St. Olaf College to Prof. Loebach
- Plastic framework designed and built to house electrical equipment
- Necessary electrical wiring was calculated and wires stripped, crimped and soldered in place
- Speakers and lights were installed and connected to relays and power sources
- A frame was constructed so that the arc can be moved 20 degrees up and down, and rotated from horizontal (to test azimuth localization) to vertical (to test elevation localization)
- A custom written program was designed in Matlab and used to control the device via National Instrument interfaces

Pilot Study of the SoLoArc (please see poster 787.14 for more detail):

- Pilot study conducted as a part of a laboratory on Sound Localization in a Sensation and Perception course at St. Olaf College
  - Participants centered under SoLoArc with head stabilization pillow
  - Unobstructed pinnae equidistant from -90 and +90 degree speakers
  - Indicated location of a 1000 Hz 500 msec tone using a laser pointer
- Data compared to headphone based synthetic ITD (440 Hz sinusoid with interaural delays varying between +/-640 μsec) and ILD (6000 Hz sinusoids varying by +/- 21 dB between right and left headphones

Acknowledgements

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Apparatus Design

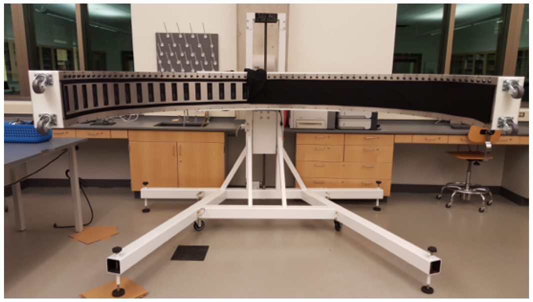


Figure 1A. SoLoArc in Azimuth configuration: The apparatus, on its face, showing the speaker and light positions and sound permeable cloth partially removed. The participant would be seated with their head at the convergence focal point directly between the -90° and +90° speaker.

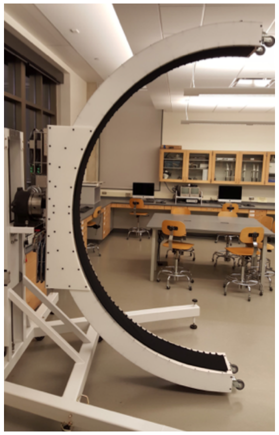
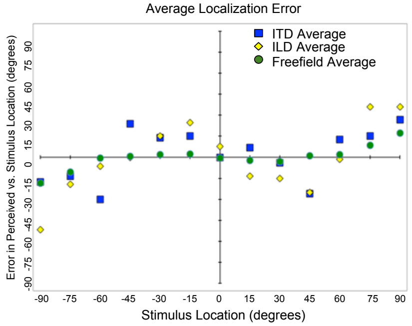


Figure 1B. SoLoArc in Elevation configuration: The device rotated into vertical position. The participant would be seated with their head at the convergence focal point directly between the -90° and +90° speaker.

The free-field sound localization apparatus incorporates both auditory and visual inputs in a 180° arc with a 4' radius (See Figure 1A and B). The speakers are placed at 5° intervals on the arc with LED lights at 2.5° intervals. The apparatus is mounted to a stand that allows horizontal (azimuth) and vertical (elevation) positioning and raising and lowering by 20 degrees to accommodate participants of varying heights. The subject, seated at the focal point of the AV field, will indicate source localization in azimuth and elevation using a head-mounted eye tracking device.

Results

Figure 2. Average localization error comparing free-field presentation with the SoLoArc and ITDs and ILDs presented over stereo headphones



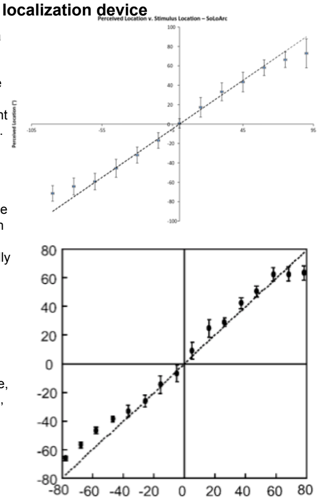
Average deviation (y-axis), obtained by subtracting the perceived angular location of the sound source from the actual location (x-axis). Blue squares are average deviations for ITD cues presented over headphones, Yellow diamonds, ILD cues presented over headphones, and green circles are free field presentations using the SoLoArc. Deviations closer to zero indicate better performance.

Figure 3. Overall performance of SoLoArc vs. another documented localization device

Comparison data showing average response localization in the azimuth position using two different free field devices.

(A) SoloArc data show higher accuracy and fewer errors at the zero speaker with deviations in accuracy gradually increasing with outward angular position.

(B) Comparison data from prior study (Doucet, Gullermot, Gagne, Leclerc & Lepore, 2005) using a comparable free field setup.



(Figure adapted From Doucet et al, 2005)

Discussion

The SoLoArc has provided significant didactic opportunity for undergraduate Neuroscience students involved in its construction, and due to its durability, will continue to provide such opportunities for years to come.

Experience gained from SoLoArc design and construction:

- Conceptualization and design of a device with the goal of overcoming an obstacle in performing hypothesis driven empirical research.
- Working with others with a varying level of mechanical skill and expertise.
- Extensive experience in wiring an electronics-heavy device.
- Troubleshooting construction issues as they arise, keeping in mind a limited budget and overall end goals.
- Creation of a program to allow for presentation of stimuli in auditory and visual modalities

Benefits to current and future students:

- Experimentation using a free-field localization of audiovisual stimuli
- Further development and troubleshooting of computer programming to develop new stimuli, methods, or improve existing code.
- The availability of a highly dynamic free field localization device for the investigation of further research questions in cognitive neuroscience.

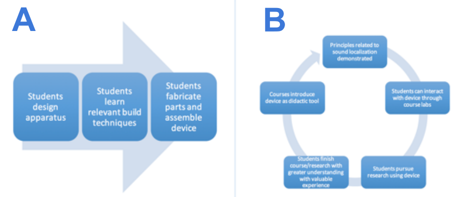


Figure 4. Visual representation of learning paradigm We believe the design and construction of the SoLoArc provides cyclically didactic benefits to current and future students. (A) represents the contributions of those who designed and constructed the SoLoArc, leading to (B), the benefits of the availability of the SoLoArc to current and future students in Neuroscience and in related fields of research.

Future Directions

With the functionality of the SoLoArc firmly established, a number of uses for the device have been identified. These plans include use in independent research (such as studying pinnal influence on vertical sound localization and hemodynamic correlates of cognition), within laboratory courses at St. Olaf College, and for localization studies with cochlear implant patients through ScogLab. The durability of the apparatus will allow for additional research opportunities for students and faculty alike for years to come.

Courses in which the SoLoArc apparatus will be utilized:

- Sensation and Perception: Sound localization labs
- Psychology of Hearing
- Introduction to Cellular and Molecular Neuroscience

Research in which the SoLoArc apparatus will be utilized:

- Pinna shape influence on vertical sound localization
- Hemodynamics correlates of cognition
- Sound localization ability of cochlear implant users

References

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